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CONTENTS.

PAGE.

The Cost and Value of Scientific Investigation 101

Obituary: The Late E. J. Wortley, C.M.G., O.B.E. 103

Cultivation Costs and Labour Requirements for Crops Grown on the College Farm ... 104

Miscellaneous Notes 115

A Discussion of Researches on the Sugar-Cane Froghopper (Homop., Cercopidae)... 116

Microbial Activity as Influenced by Root Excretions 123

Chemical Notes 124

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THE COST AND VALUE OF SCIENTIFIC INVESTIGATION*

IT will be generally admitted that present day agriculture has ceased to be the empirical industry of former times and has now so definite a scientific basis that it requires technical guidance and investigation if it is to maintain its present status and progress. Stated in other words, any country which neglected to provide for this need would soon find the agricultural section of the community placed at a serious disadvantage in relation to its more foreseeing neighbours and competitors. Yet the provision of funds for the purpose offers a problem fraught with perplexity, and this perplexity arises from the fact that the cost of such investigation conforms to no ordinary system of accountancy. While the benefits, in the sum, are undoubted, it is rarely possible to say that this or that particular investigation has been financially profitable. These are the conditions where the small unit cannot undertake the cost, for it cannot afford the risk; and in most countries, the industry is built up of such small units.

That is one aspect of the case but there is another. Agriculture is in all countries a basic industry and in many the dominant industry. It is more than that; it is a mode of life of a large section of the community. Agricultural prosperity materially affects the prosperity of the community as a whole; it may even be said without gross exaggeration that a prosperous agriculture is essential to the health of all communities. There is, thus, a very pertinent argument in favour of the cost of these investigations being in part at least borne by the community as a whole—in other words, that it shall be state-aided. These two arguments have, in most countries carried the day and agricultural investigations are, for the most part, considered to be a function of government and the cost, thus, centralized. This has two disadvantages; in the first place, though we are told never to look the gift horse in the mouth, it is indubitably true that the mass of humanity has relatively little respect for something it does not pay for and the practical result of this attitude is the difficult problem of how to bring the results of investigations so conducted effectively to the notice of the practising

* Article by H. M. L. reprinted from *The International Sugar Journal*, Vol. XLIII, p. 333-334.

agriculturist. In the second place it means a divorce between theory and practice which encourages the investigator to follow the, to him, more interesting paths of theory.

It would form an interesting commentary on this theme to follow out the way these problems have been answered in the different countries and to trace the degree of success attained in each case. Such a study cannot be undertaken here. No finality, universally accepted, has yet been attained and individual attitudes vary widely. To some, such investigation is as vintage port, to be drunk only with due solemnity in the inner chamber—that is the view of some investigators; to another it is the champagne of life acting as a solvent of all and every care; to a third it is the whisky of modern times, dear and nasty; to a fourth, it is the poison which represents all that is evil. In view of this divergence of opinion on the value of investigations of this nature, it is as well that, from time to time, the community should be reminded of the debt it owes to the investigators. Such a reminder lies before the writer in an article entitled "Research on Sugar Plants and Some Practical Adaptations" by E. W. Brandes and appearing in the *Archief*.* The paper is confined to a consideration of the work sponsored by the United States Division of Sugar Plant Investigations during the past 20 years and the conclusion drawn is that its value approaches a thousand million dollars of conserved capital and added national wealth. That is the estimated value of the direct gain; indirectly, half a million persons who might otherwise be on relief have been given a means of livelihood. The cost of this research is not given but it is noted as relatively little.

In this period of 20 years a series of interruptions have marred the smoothness of the path of the several sugar industries due, for the most part, to natural causes, principally disease. The situation in the Southern States, culminating in 1926, was so ominous that the death knell of the industry was confidently sounded. Even the minor poultry industry was claimed to be more profitable. The cause was the unnoticed introduction of the virus disease, mosaic. As is well known, the remedy was found as the result of an elaborate programme involving the combing of the world for breeding material. In 1927, when the first new variety was introduced, the nadir had been reached with the production of under 50,000 tons sugar. The rise has since been continuous as the result of further varietal introductions until, in 1938, production had attained nearly 500,000 tons—a ten-fold increase from approximately a doubled acreage. Puerto Rico has the same story to tell, though with less emphasis for, with its more variable climate, the disease was responsive to an adequate degree of control by rogueing in certain tracts.

In arriving at an estimate of the return from the investigations conducted, all production with released plant material where failure had resulted from low yield and part of the production on lands jeopardized but not actually abandoned is accounted as credit. Further credits are the capital investment in factories, machinery, plantation railways and specialized equipment in areas abandoned or marked for abandonment. On this basis the industries of the Gulf States owe to these investigations over a period of 14 years $350 million with the present employment of 60,000 workers or calculating three dependents to each worker, a livelihood of 240,000 persons.

The first mosaic resistant variety was supplied to Puerto Rico in 1919 since which date the yield of sugar per acre has increased by over 100 per cent. Though the early investigations here were the work of the Division, they have been carried on by the local institutions, to the work of which further improvements are due. For this reason only half the annual increments in acre-yield are taken in credit, but even so, these total $225 million while salvage of capital investment totals $10 million with livelihood for 25,000 workers or, with their dependents, 100,000 persons.

These are the conclusions drawn in respect of the cane sugar industry. The history of the beet sugar industry runs on parallel lines. In the decade preceding 1934 the average acre yields dropped in some of the Western States from 15 to 5 tons or less, not taking into account the acreage abandoned. This resulted from the ravages of the sugar beet virus disease known as curly top. It is the record of an area newly opened up under reclamation projects with high hopes, a brief period of fine prospects followed by failure and ultimate abandonment with factories, each representing some half million dollars, left derelict. The nadir here was reached in 1929 when work on the disease was commenced. 1931 saw the first evidence of the road to recovery in the development of resistant varieties and, by 1934, the variety US 1 was introduced for cultivation by the farming community. Varieties US 34, US 33 and US 12 followed in quick succession and, by 1939, some 235,000 acres of the 300,000 acres subject to curly top were planted to varieties arising from these investigations. As a direct result the cultivation of sugar beet has been renewed in California, Nevada, Idaho, Utah, New Mexico, and western California; dismantled factories have been re-equipped and new factories erected. These, it is stated, are the consequences emerging from the work of a dozen or more scientists.

In this case the capital invested in farm lands, farm equipment, irrigation systems, factory equipment, transportation and power facilities directly concerned in sugar production is placed at $350 million, to which must be added that of the important subsidiary industries of supplies and services and the livestock industry supported on the sugar beet industry's by-products. Nearly one-fourth of this capital, say between $80 and $100 million was jeopardized. Credit is reasonably taken, therefore, for the major portion of this as well as of the $25 million representing the recent expansion of the western industry.

* *Archief*, 1941, 2, pp. 74-84.

If these are what may be termed the direct consequences of these investigations, the indirect consequences are of hardly less importance. For nearly a century the State's beet industry had been dependent on Europe for its seed supply and it required the impetus of the demand for specialized varieties to bring home the precariousness of such a dependence. Methods had to be and have been, through the sponsoring of the Division, worked out for the raising of beet for seed and they differ radically from the conventional European methods. These "garden" methods have been replaced by short occupancy of the land and the abundant use of machines. 1939 saw the production of over six million pounds of seed of the resistant varieties and the total of home raised seed, which includes that of leaf-spot resistant varieties, in that year amounted to nearly 14 million pounds.

A brief indication is given of what this means to the industry under the present war conditions by a comparison with what happened during the last war when meagre supplies of seed were obtained from Germany through the blockade under bond prohibiting resale and exacting the return of the sacks. The possibility of unlimited expansion, should the world situation demand it, now exists and it is a security of a national industry the value of which is incapable of monetary expression.

These are the results of investigations which have already been capitalized. Much further work is in progress, not yet but soon likely to be capitalized. Such is the work on cold tolerance of the sugar cane and on black root and leaf spot of the sugar beet. In the first of these, advantage is being taken of the discovery in central Asia in 1936 of cold-resisting wild canes. The difficulties experienced here lie in the very different flowering periods and have been overcome by using the reversed seasons above and below the equator, growing the male parent in the North and the female in the South and transmitting the pollen by air. Thus was the first cross effected. The subsequent back cross was made locally by artificial advancement of the flowering of the commercial cane in the photo-period house.

Black root and leaf spot are two diseases which have caused trouble in the Intermountain and Pacific regions. Seed treatment, rotations which starve the pathogenic organisms plus other field sanitation methods have largely controlled the toll taken by the first of these diseases. The latter is being met by the same means as curly top, by resistant varieties, and US 217, released in 1938, has a high degree of resistance with a better performance than the European brands. A new release is US 200 × US 215 in which, besides resistance, advantage is taken of first generation hybrid vigour. Of this only a limited amount of seed, some 200,000 lbs. in 1939, is available.

Such are the results attained in the relatively brief span of activity of the Division. It may be argued that the law of diminishing return will come into play, but it has to be realized that the incidence of any new disease constitutes a new starting point.

OBITUARY

The Late E. J. Wortley, C.M.G., O.B.E.

It is with great regret that we have to announce the death in Barbados of Mr. E. J. Wortley on the 27th April, 1942. Mr. Wortley had recently retired from the post of Director of Agriculture of Trinidad and Tobago where his loss will be keenly felt.

In the Colonial Agricultural Service, Mr. Wortley had a long and distinguished career; he joined the Jamaica Department of Agriculture in 1902 as Junior Assistant Chemist, subsequently holding several posts of increasing importance in that Department until he was appointed Director of Agriculture of Bermuda in 1913. In 1920 he was appointed Director of Agriculture, Nyasaland and, ten years later, Director of Agriculture of Trinidad and Tobago, an appointment which he held until his retirement in January 1942. Official recognition of his services was marked by the award of the O.B.E. in 1926 and the C.M.G. in 1935.

The years during which Mr. Wortley was Director of Agriculture in Trinidad presented problems of agricultural policy of almost unprecedented difficulty, as this period was one of unstable prices for almost every kind of agricultural produce; in Trinidad the problem was further complicated by the spread of Witchbroom disease of cocoa. Much was done to alleviate the resulting agricultural depression by the development of a banana export industry for the inception of which Mr. Wortley was almost entirely responsible and which met with considerable success for a number of years.

Mr. Wortley will be remembered by numerous former students of the College of which he was a Governor from 1930 until his death. He took every opportunity to foster the closest co-operation between the College and the local Department with considerable benefit to both institutions and much of the past and current research work would have been impossible had not the resources of Departmental experiment stations been so freely placed at the disposal of the College staff.

As head of the Department of Agriculture Mr. Wortley was justly popular with his staff; he was always fully informed with regard to the activities of the various branches and his criticisms and suggestions were invariably stimulating and constructive. In his relations with the agricultural community he was always sympathetic towards the needs of planters and farmers and he was indefatigable in his efforts to assist them.

Mr. Wortley resigned his appointment for reasons of health and it was hoped that he would enjoy many years of retirement. His death following so soon upon his withdrawal from official life will be deeply regretted by his numerous friends.

CULTIVATION COSTS AND LABOUR REQUIREMENTS FOR CROPS GROWN ON THE COLLEGE FARM

BY

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THE trend of agricultural policy in many of the Caribbean islands appears to be towards expansion in peasant settlements in order to increase the quantity and variety of home produced foodstuffs and to establish a settled, contented, and as far as possible a self-supporting peasantry. This does not imply the neglect of export crops ; indeed, by introducing better and more skilful methods of farming and soil management, the revenue from the sales of produce may be even greater than where a system of one crop specialisation is followed. It is generally conceded that successful development in this direction should be combined with the introduction of a suitable system of mixed farming which in turn would entail expansion and improvement of the requisite livestock. The stock would not only add to the variety of produce that the peasant farmer would have for sale or home consumption, but would also make it possible for him to maintain the fertility of his soil by the economic utilisation of crop residues and farmyard manure. A sound rotation of crops for each settlement would have to be evolved, and presumably, in any year, each holding would be appropriately apportioned between food crops, money crops and forage crops. The forage crops would not only be used to provide the bulk of the stock rations, but under good management would be operated so as to utilise the natural capacity of grasses and legumes for the recuperation of soil fertility. Forage grasses are also almost indispensable for the prevention of erosion on sloping land by means of strip cropping and contour "fences".

For many reasons, the successful establishment, or maintenance of peasant settlements on a large scale in the West Indies is not an easy project, but it is one which requires to be initiated at no distant date for the sake of the general welfare of the whole community. It entails a change over to the growing of a much higher proportion of annual food crops in contrast to existing systems of agriculture which are largely dependent on perennial export crops. In the wet tropics, plantation crops in general provide more effective protection than annual crops against leaching and soil erosion, and for the successful development of any permanent settlement, some system of agriculture will have to be evolved which will not only ensure the maintenance of soil fertility but will also permit the cultivation of a proportion of relatively wide-spaced annual crops in areas of heavy rainfall. The problem is further complicated by the fact that in many of the islands there is a real land shortage so that areas available for settlement are limited and not uncommonly are located on steep slopes ; in fact many of them are too steep for cultivation or alternatively are marginal lands either basically of low fertility or already run down and poor in plant nutrients as a result of exploitation and exposure in the past. Where the land shortage is serious the area allocated per head of population will have to be limited, which in turn involves the adoption of a relatively intensive system of cultivation in order to provide a reasonable living for a peasant family. A further complication lies in the fact that each island has its own peculiar local problems. From one island to the next, and even from one little community to the next within each island, it is not only the soil, the climate, the existing crops and cultural conditions which vary significantly, but even the people and the whole social and economic structure of the community may be radically different. It is this fact which makes it quite impossible to prescribe a universal panacea which will provide an effective solution to the peasant settlement problem throughout the Caribbean. Very general principles may be laid down, but in the practical application of these in detail, the best method of approach will have to be thought out and developed individually for each distinct zone or locality.

Without further elaboration, enough has been said to show that the difficulties of successful peasant settlement are not few and far to seek, though none of them appears to be insoluble. The lack of information and accurate data relative to the growing of annual arable crops in the West Indies is a further temporary handicap to the rapid development of thriving settlements. Without scientific data it is hard to decide what acreage of land each peasant can effectively cultivate, what rotation of crops he should use, what proportion of his land each year he should allocate to food, money or forage crops, and other similar practical details for the operation of each holding. For this purpose, it is thought that the following facts and figures extracted from the records kept at the farm of the Imperial College of Tropical Agriculture may be of interest in revealing how important it is that fuller and more apposite data are urgently required if the many problems of organisation and management are to be effectively solved. But to avoid possible misinterpretation of these records, it is necessary to give a preliminary account of the general character and organisation of the College Farm, and of the cultural conditions under which the data have been compiled.

The College Farm

The farm as at present constituted comprises some 60 acres of arable land on the southern portion of the grounds of the Imperial College of Tropical Agriculture, Trinidad. The College is situated on the narrow belt of flat land lying imme-

diately south of the Northern Range of hills. This belt forms an intermediate zone of transported soil linking up the hills to the north and the Central Plain of Trinidad to the south. The soil type is a light silty to sandy loam with a proportion of coarser, gravelly particles ; it is rather low in general fertility and has a tendency towards acidity. Topographically, the land is flat and admirably adapted to implemental cultivation with animal or power draught. There is a general slight slope to the south, which facilitates good drainage, and that, combined with a light soil type makes it possible to work the land in a remarkably short time after heavy rains. For the last decade, 1930–40, this whole area has been kept under cultivation as a small arable farm growing a number of annual tropical food, money, and forage crops. The farm has not been run as a commercial unit but has been planned primarily as a teaching centre where, on a small scale, students could be given practical demonstrations of the cultivation and care of a large variety of tropical crops together with instruction on the maintenance of soil fertility on arable land in the tropics. In addition to this primary function, the farm has also been extensively used for the carrying out of a number of field experiments undertaken by students doing research work on various problems of agricultural importance. The climate in Trinidad is typical of the insular tropics with a fairly heavy and well distributed rainfall for some nine months in the year, and a drier but by no means a drought season for the remaining three months. There is therefore really no closed season for the vegetative growth of crops, although the rate of growth is greatly reduced during the dry season, which is also the time of year when the majority of the field crops ripen most satisfactorily. In fact, in the same calendar month, many short season crops may be found in adjoining fields at several different stages of growth from germinating seed to ripe produce, and crops like maize or woolly pyrol may be sown with equal chances of success at any time in the wet season from May to December. To avoid leaching and soil erosion, the general policy has been to keep the land under a good vegetative cover for as much of the year as possible, and this policy together with the cultivation of many short season annual crops has meant that two or even three crops have been taken off a good proportion of the fields annually. The cropping system is therefore definitely intensive, and the fertility of the soil can only be maintained at a reasonable level by regular and fairly heavy dressings of both artificial and organic manures together with the introduction of an occasional leguminous green manure crop.

Equipment

The average number of work animals kept on the farm is five pairs of oxen, two mules, and one donkey, and except in the vegetable garden, experimental areas, and special demonstration plots, much of the cultivation is done with the aid of animal drawn implements, as for example ploughing, harrowing, ridging, or inter-row cultivating. In addition, a good deal of hand work is required with most crops for the finer operations as weeding, thinning, harvesting. The choice and variety of animal drawn implements available at the farm is very much greater than would be found on any small holding, but with a few exceptions such as machine sowing with the maize planter, most of the cultural operations carried out with animal draught on the farm could equally well be done by any progressive peasant farmer with his own cattle and a simpler but effective range of cultural implements. Furthermore, in order to accommodate a wide range of field crops every year, the College Farm has been divided into a large number of small fields varying in size from $\frac{1}{2}$ to 5 acres. The cultural unit is thus very small, and the general economy of cultivation at the farm should not differ greatly from that on a small-holding where working oxen are kept.

The buildings and store-rooms are of course much better and more extensive than would be found on a peasant farm of the same acreage, but in actual fact apart from the educational facilities, most of the operations carried out at the steading are again within the compass of the small-holder. Thus, most of the seed crops are sun dried and then threshed by hand or by trampling with oxen or by rolling with a land roller. Hand winnowing on windy days is the method used for cleaning the seed of chaff, dust, and other extraneous matter. The cattle are housed every night in an ordinary wooden cattle pen where the first stage in the manufacture of farmyard manure is completed as usual. Thus while the facilities at the steading are more extensive and structurally better than those that might be found on a commercial farm of the same size, they do not lessen significantly the actual cost of the various farm operations. For these reasons it is thought that the appended figures may be taken as at least an approximate index of the labour and other requirements of a peasant farm operated on similar lines.

Records

A detailed system of records has been in operation since 1928, by means of which day by day the cultural work, the labour, the materials, the produce issued or received at the steading are all allocated fairly to the particular fields or crops to which they rightly belong. After any crop has been harvested, the records are used to provide a summarised analysis of the total cost of production, the quantity of marketable produce, and an estimate of the net profit or loss per acre. In the following data all overhead expenses such as interest on capital, the cost of maintenance of roads, drains and buildings, the overseer's salary, have been purposely omitted from the costings figures on the grounds that the overhead charges at the College Farm which is primarily a teaching and research centre can in no circumstances be at all representative of any commercial holding. Furthermore, it is obvious that the overheads for

different peasant holdings must vary enormously depending on the type of holding, the land rental, the marketing facilities and so on, and it really becomes impossible to quote a general figure for this item. Actually the overhead expenses on any peasant holding should be only a small percentage of the total cost of growing any one crop, as the land rental is likely to be low and the outlay on equipment and supervision should be small. The appended data, therefore, have been restricted to simple running costs for the cultivation of the specified crops exclusive of overhead, marketing, and other expenses not immediately concerned with the sowing, cultivating, harvesting and threshing of each crop.

The working day at the farm is one of eight hours from 7 a.m. to 4 p.m. with an hour off for lunch. The labourers are mostly of East Indian extraction and comprise men, women and boys in about equal proportions. The 1930–40 decade for which the data have been compiled represents a period before serious inflation of local labour rates had occurred, and wages and costings* are based on the following standards for an ordinary field labourer working an eight-hour day:—

	1930-36	1937-40	Average for Decade.
Man ...	40c.	44c.	42c.
Woman ...	30c.	36c.	33c.
Youth ...	20c.	24c.	22c.

Actually, while the stockmen and a few of the permanent and more skilled fieldmen are paid by the day, many of the farm operations are given out by the task to encourage the quick worker and ensure a reasonable daily output of work per head. The rate of pay per task is based on the prevailing daily wage, being fixed for men at 40 cents up to 1936 and then increasing to 44 cents after that date. When paid by the task it was possible for good fieldmen by starting early and working hard to complete 1½ or even 2 tasks in a day, and so earn double pay. Generally, however, the men prefer to go home as soon as they have completed one task so that it is not uncommon to see them leaving work by midday having finished their task and earned the equivalent of a full day's pay.

Detailed costs for the feeding and care of the draught animals are kept, and for the ten year period the average figures for the inclusive cost per animal *per working day* were as follows:—

Mule 48c. Ox 40c. Donkey 20c.

These are costs based on the average number of days in the year that each class of animal was at work, namely 150 full working days per draught ox and 200 per mule. If the animals could be used for cultural or other farm work for a larger proportion of the calendar year, the charge per working day would be proportionately reduced as the cost of feeding and maintenance would not alter. On a small holding, however, the number of working days per year that the draught animals can be effectively used is likely to be less and not more than on the College Farm where month by month a wide range of cultural operations is always in hand.

These costings for draught animals include the cost of the stock rations. At the farm, the livestock is fed on the soiling system, largely on cultivated perennial fodder grasses cut daily and carted to the animals in the form of fresh green herbage. These fodder crops chiefly elephant and Guatemala grass, are cut over in rotation when the herbage is only 6 to 10 weeks old and when in consequence the nutritional quality of the roughage is about equal to that of good meadow hay. Depending on the species, the season of the year and the maturity of the herbage, the animals are provided with 60 to 100 lb. of green roughage per head per day, which it is estimated is an adequate ration for a 1,000 lb. ox on light work. At the busy seasons of the year when the stock is being worked hard, each animal is given, at its midday meal, in addition to chaffed roughage, the following concentrate mixtures:—

	Percentage by Weight.
2 lb. Coconut Meal	33·3
2 lb. Bruised Maize	33·3
6 oz. Ground Blood Meal ...	6.3
2 oz. Minerals—mainly Salt and Bone Meal	2.1
1 Pint Molasses	25.0

This particular mixture was chosen because it is nutritious and palatable, is well balanced in its protein, carbohydrate and mineral content, and can be purchased cheaply as practically all the constituents are local products. The actual cost worked out at some 10 cents per head per day or about one penny per pound of the mixture. This concentrate ration along with the liberal supply of young green roughage has served to keep the animals in excellent health even at the busiest seasons of the year. It must be admitted that the concentrates do add a little to the maintenance cost per head of livestock, and when there is a plentiful supply of good succulent herbage, it is questionable whether the draught oxen really require any concentrates.

Crops

Data are given for two cereals, two pulses, two roots, and two money crops, namely maize and swamp rice, woolly pyrol and pigeon peas, yams and sweet potatoes, plant and ratoon sugar cane. With good cultivation, all these crops should grow satisfactorily under conditions obtaining at the Imperial College of Tropical Agriculture, and may be expected to give reasonable yields of marketable produce in an average season. They are representative of a good range of crop types including some

* These and all subsequent costings figures are quoted in Trinidad dollars and cents which are linked to sterling at the rate of $4.80 to the £1.

DATA FROM I.C.T.A CROPS FOR THE DECADE, 1930-1940

	Maize.	Swamp Rice.	Woolly Pyrol.	Pigeon Peas.	Sweet Potatoes.	Yams.	Sugar Cane.	
							Plant.	1st Ratoon.
No. of Crops...	57	7	24	7	19	9	8	10
Total Acreage	142.70 acres	20.70 acres	59.67 acres	9.52 acres	34.64 acres	12 acres	21.03 acres	26.67 acres
Crop Period in Weeks :								
Average	17	20	13	42	23	34	83	52
Extreme Range	15 to 20	16 to 23	10 to 16	41 to 44	16 to 30	30 to 37	73 to 102	47 to 58
Labour Requirements per Acre :								
Man days	25	32	15	43	52	139	75	44
Woman and Youth Days ...	38	27	21	133	69	115	66	36
Total Labour Days ...	63	59	36	176	121	254	141	80
Mule Days ...	2	1	2	9	1	6	9	4
Ox Days	12	12	9	17	16	11	24	8
Total Animal Days ...	14	13	11	26	17	17	33	12
Cost of Cultural Operations (per cent. of Total) :								
Preparatory Cultivation ...	32	35	39	15	31	12	14	—
Manures and Manuring ...	23	9	13	3	10	13	20	16
Seeds and Sowing ...	8	32	9	11	17	21	9	2
Post-Sowing Cultivation ...	27	2	21	37	29	43	27	35
Harvesting and Threshing ...	10	22	18	34	13	11	30	47
Cultivation Costs per Acre :	$	$	$	$	$	$	$	$
Average	36.56	39.01	26.85	67.77	67.85	174.90	107.14	44.18
Extreme Range	9.75 to 83.47	26.82 to 54.37	8.46 to 85.13	34.88 to 108.66	33.99 to 129.25	120.07 to 227.66	69.34 to 137.31	30.03 to 59.64
Yield per Acre :	lb.	lb.	lb.	lb.	lb.	lb.	tons	tons
Average	2,384 (dry cob)	2,474	339	2,289 (green pod)+159 (dry seed)	4,801	16,125	52.30	28.96
Extreme Range ...	613 to 4,766 (dry cob)	1,727 to 3,590	59.6 to 836	—	1,924 to 8,798	9,203 to 21,894	29.02 to 71.68	19.79 to 42.85
Selling Price ex Farm per lb. of Produce :	cents	cents	cents	cents cents	cents	cents	$	$
Average	1½ (dry cob)	1½	4½	2 4	1½	1½	2.80 per ton	2.85 per ton
Extreme Range	1 to 2½ (dry cob)	1.2 to 4	3 to 8	2 to 2½ 2 to 8	1 to 4	1 to 2½	2.64 to 2.88	2.40 to 3.35
Production cost per lb. of Produce : ...	cents	cents	cents	cents cents	cents	cents	$	$
	1.53 (dry cob)	1.58	7.92	— 13.81	1.41	1.08	2.05 per ton	1.53 per ton
Gross Revenue per Acre :	$	$	$	$	$	$	$	$
Average	35.93	36.73	14.21	49.81	62.08	269.33	129.27	82.80
Extreme Range	9.19 to 95.32	16.98 to 54.17	1.79 to 33.44	10.07 to 89.63	28.86 to 109.97	161.44 to 350.30	83.62 to 189.20	51.71 to 139.91
Profit or Loss per Acre :	$	$	$	$	$	$	$	$
Average	—.63	—2.28	—12.65	—17.96	—5.77	+94.43	+22.13	+38.62
Extreme Range	—59.12 to +53.15	—29.24 to +12.34	—75.73 to +10.27	—90.66 to +21.00	—60.49 to +28.82	+13.69 to +169.46	—20.83 to +51.89	+9.62 to +88.30
Per Crop Week	—.037	—.114	—.973	—.428	—.251	+2.78	+.221	+.744
ESTIMATES FOR 1941 *								
1941	$	$	$	$	$	$	$	$
Cultivation Costs per Acre ...	116.00	138.00	71.00	133.00	204.00	311.00	156.00	81.00
Market Price per lb. of Produce	.02¼ (dry cob)	.02½	.06	.04 .10	.03	.04	3.70 per ton	3.70 per ton
Gross Revenue per Acre ...	53.60	61.75	20.40	107.50	144.00	645.00	192.00	103.00
Profit or Loss per Acre ...	—62.40	—76.25	—50.60	—25.50	—60.00	+334.00	+46.00	+22.00

**Footnote.*—These data are not for actual field crops, but are merely estimates at 1941 rates for crops giving the average yields recorded in the table.

The standard wage rates for 1941 were taken to be :—Man 80c. ; Woman 52c. ; Youth 40c. For calculating the gross revenue the prices quoted are the maximum retail prices fixed by the Food Control Board in December, 1941.

light and some heavy in their labour demands, short and long season annuals, and food and money crops. They have been selected from an extensive list* of crops grown at the farm because they are familiar to the peasant farmer and have been sown regularly as commercial crops on a small scale over the ten year period. It is realised that they do not cover the full range of crops grown by peasants, but apart from perennials, most of the other crops cultivated by the smallholder could be allocated to one or other of the main classes for which data are recorded. Swamp rice has been included as one of the type crops, because where conditions permit of its cultivation it is a very important food crop of peasant farmers in the tropics. Actually, at the College, the rice is grown on the northern edge of the Caroni plain about half a mile to the south of the College Farm proper. The soil on the rice fields is a heavy fine-grained alluvium which is admirably suited to the cultivation of rice in the wet season when the natural drainage channels bring a considerable volume of flood water to the Caroni plain. It is this flood water which is used for irrigating the rice crop. In Appendix II, data are recorded to show the cost of maintaining and utilising an area under Guatemala grass grown as a soiling crop for feeding to cattle. These figures represent actual values recorded for one of the College fields in which a fodder crop of Guatemala grass has been established and has continued to give a good yield of herbage steadily for the last ten years. These data have been relegated to the appendix as they are not strictly comparable with those given for the annual crops which included ploughing and sowing costs. They do serve to give an idea of the upkeep costs of an established field of a perennial tropical fodder crop.

Commentary

In analysing the data it is necessary to keep in mind the general character of the farm from which they have been compiled. The College Farm is situated on relatively flat arable land easily adapted to implemental cultivation, and the figures cannot be applied indiscriminately to similar operations or crops in hilly country or on steeply sloping land where animal draught may be ruled out and where precautions against soil erosion are certain to be more elaborate and expensive. Even on the adjacent alluvial soil of the Caroni Plain of Trinidad, the amount and cost of cultivation are likely to be greater than on the College Farm with its relatively light free draining soil, but the additional cultivation on the heavier soil may possibly be more than offset by increased yields. The figures already quoted for wage rates and the cost of the draught oxen per working day must also be kept in mind.

Seasonal Effects

The number of weeks required to mature any one type of crop shows considerable variation. This may be taken as indicative of major seasonal or climatic differences from year to year, as with the exception of maize and woolly pyrol the annual crops cited have all been sown and harvested at definite seasons in each year. The tremendous range in yield for the same standard of cultivation is further evidence of the important part season plays in crop growth, even admitting the fact that differences in fertility from field to field on the College Farm may account for part of the variation in yield. It would appear therefore that the peasant farmer growing these crops under similar conditions is largely dependent on the season for good yields, and that in a climatically bad year, even with a high standard of cultivation, his returns will be decidedly disappointing. The profit and loss account as tabulated further emphasises this fact. For all the crops when the yield is good, *i.e.* when the season is favourable, a reasonable profit is recorded, whereas in a bad year with the possible exception of yams and sugar cane there is a considerable deficit even in a balance sheet in which no charges for overhead expenses have been entered. The influence of season on yield of produce and on profits is most marked in the case of short season crops like woolly pyrol where the crop is not sufficiently long in the ground to recover from a temporary set back.

Cultural Operations and Labour

The number of animal days is a noticeably small percentage of the total labour days required to bring any given crop to maturity. The proportion of animal days is higher in the case of short season crops, but in no case does the number of animal days exceed one-third of the total labour days required by any crop, and its average value for all the crops cited is only 18 per cent. of the manual requirement. When it is considered that the draught animals at the College Farm are usually worked in teams of two or even four per implement, the number of full working days per crop on which any one animal can be effectively used for draught purposes on a small peasant holding is distinctly limited. In the circumstances, only double or multiple purpose breeds of livestock capable of giving some productive return—milk, meat or young animals—in addition to work could be profitably maintained by the small holder practising mixed farming, and purely draught animals such as horses or mules would have to be ruled out for economic reasons. The data further indicate that in the insular tropics the cultivation of most of these annual arable crops still demands a considerable amount of manual work even when draught implements are available. Actually, the cost of labour, including animal labour, accounts for a large proportion of the total outlay in the cultivation of all these crops. The materials used, *i.e.* the seed and fertilisers, are responsible for only about 15 per cent. of the whole cost of cultivation, even although the rate at which fertilisers are applied to the College fields is relatively high. The wage bill appears to be the controlling factor in the cost of cultivation. This makes the recent large increase in the minimum rate of pay of all

* For list *see* Appendix I.

classes of labourer in Trinidad of immediate importance, and it is for this reason that the estimates of revenue, cost and profit per acre for 1941 have been included as a footnote to the tabulated data. Rates of pay are still tending to rise, and it is reasonable to assume that estimates of costings for 1942 would be even higher than those for 1941.

Yields

Average yields are not high, but they are on the whole good considering the rather poor soil type on which the crops have been grown. The full data show that yields have been satisfactorily maintained over the ten year period, and there are no indications of diminishing yield which, with an intensive system of farming, speaks well for the rotation of crops and the manurial dressings used.

The sweet potatoes give a consistently low yield by common standards, and the field conditions at the farm are apparently ill-suited to this crop. In most years the potatoes grown at the farm have suffered from drought or pest attack in one form or another, and after a promising start have given poor returns. In a more favourable environment it is considered that with good cultivation, sweet potatoes should give a more profitable return than the figures from the farm would lead one to expect. The yield of pigeon peas is good, but the cost of hand picking the peas over a prolonged harvest period has swamped any chance of high profits. This is a crop that is particularly liable to suffer from praedial larceny, and it is suspected that the true yield of pigeon peas grown on the College Farm may be considerably more than the figures quoted. It is of course quite impossible to give any estimate of the percentage of the total crop that may have been stolen. The yields of yams show less variation than any of the other crops, and are consistently good for a light soil ; this is undoubtedly one of the best paying crops grown on the farm, in spite of its high demands in man days and materials. Maize yields* are satisfactory but not outstanding ; the small monetary return from this crop is not so much a reflection of poor yields but rather of the fact that its price locally is low relative to that of heavy yielding food crops like yams. The yield of paddy is relatively poorer than that of maize and the farm rice crop is one which barely pays its way ; with better control of water for irrigation, it is a crop that could be grown profitably in Trinidad. The average yield of woolly pyrol is very poor, but actually it is possible on occasions to make quite a good profit from this and other pulses. Pulse crops as a whole are particularly susceptible to seasonal effects and to insect pests, and good yields and profits can be looked for only when such crops are grown in a good season, and when this latter does not show any abnormal irregularities. Woolly pyrol at the farm has been sown indiscriminately all through the calendar year, and the average low yield recorded is not a fair index of what this and other pulses can achieve in favourable field and climatic conditions. It is true, however, that pulses are more chancy crops to grow under obtaining conditions than cereals.

The yields of sugar cane at an average of 50 tons per acre for plant cane and 30 tons for the first ratoon crop are exceptionally good, and considerably higher than the average for the rest of Trinidad. It is evident however that for an arable farm within economic reach of a sugar factory, cane is an excellent money crop to grow, and in an average season should give a profitable return per acre. Actually, the first ratoon crops all show a good surplus of revenue over cultivation costs and there is no doubt that properly managed sugar cane is less likely than most annual crops to show excessive aberration in yield or revenue from season to season.

Manuring

Any discussion of yields would not be complete without some mention of the general type and rate of application of the fertilisers applied to the crops from which the yield data have been taken. The educational and research demands on the College Farm have made it quite impossible to plan or follow a fixed rotation or even any regular manurial programme in the cultivation of the soil. In any one field, however, considerable diversification in the cropping was always arranged so that over a period of years, a large variety of different crop species was grown in turn. The particular range of crops and the order in which they are grown are partly determined by general administrative policy but as far as possible no crop was grown out-of-season and in no case were the principles of good cultivation and a sound rotation contravened. The diversity of cropping was such that roots, cereals, pulses, fibres, oilseeds, sugar cane, green manure or cover crops might all appear in turn.

Under the intensive system of cropping practised, dressings of both organic and inorganic fertilisers were considered to be essential for the maintenance of soil fertility. The inorganic fertilisers consisted in the main of the three standard artificials, sulphate of ammonia, superphosphate, and muriate of potash, but occasionally these were replaced by other chemical salts or compound fertilisers such as Niciphos, Enpekay, or sulphate of potash. In deciding the rate of application of the artificials, the general aim was to apply to each acre of arable land per annum some 60 lb. of N, 42 lb. P_2O_5 and 72 lb. K_2O which would be equivalent to a total annual dressing of 6 cwt. of a mixed fertiliser consisting of 292 lb. of sulphate of ammonia, 230 lb. of superphosphate, and 150 lb. of muriate of potash per acre. For most crops a complete fertiliser was used, although the rate per acre and the proportions in which the three constituents N, P and K were included, varied with the particular

* The maize yields quoted represent the yield in cob after a reasonable period of sun drying on the threshing floor. J. Burt-Davy quotes an average grain to cob weight ratio of 82 per cent., which is the figure that has been used in subsequent calculations to convert cob yield into seed yield.

crop and the previous manuring of the field. For instance, the mixture would usually contain a high proportion of nitrogen for a crop of maize, of phosphate for roots, and of potash and phosphate for pulses or vegetables. The cost of the artificials fluctuated with market conditions, but the average price over the ten year period 1930 to 1940 was approximately as follows:—

Sulphate of Ammonia (20.6% N)	$2.00 per cwt. c.i.f.	Port-of-Spain.
Superphosphate (18.2% w.s. P_2O_5)	$1.40	do.
Muriate of Potash (48.2% K_2O)	$2.75	do.

In addition to the artificial fertilisers, organic manures were applied periodically to every field. Farmyard or pen manure and green manure crops were the main organic manures used. In most fields, in any two or three year period, at least one green manure crop would be ploughed under and a dressing of farmyard manure at the rate of 8 to 10 tons per acre would be applied to the land. These rates of organic manuring while seemingly liberal only just served to maintain the humus in the soil at a reasonable level, but as there was no sign of decreasing yields they have evidently sufficed in conjunction with the artificial fertilisers to avoid any significant reduction in the supply of available plant foods in the soil. A large variety of different species was used for green manuring such as woolly pyrol, sunnhemp, bengal beans, sunflower, canavalia, and sesbania, and the yields of green matter ploughed under varied widely with the particular crop and the season. It is not possible to give any general figure for the amount of fresh organic material returned to the soil, but it can be stated that at the time of ploughing under, most of the green manure crops had produced a dense luxuriant vegetable cover of a depth and character that was quite satisfactory.

The quantity of farmyard manure applied was controlled, but it is certain that its fertilising quality and degree of humification must have varied considerably depending on the particular process and length of time spent in its manufacture. As a matter of fact several grades are practically always available at the farm from powdery fully rotted compost to a mixture of raw cattle dung and undecomposed litter after lying only a few days in the pen. The average quality of the organic manure applied to the field crops on the College Farm is about midway between these two extremes and might be described as a good average sample of farmyard manure as distinct from finished compost. Small quantities of the latter are manufactured on the farm by the "Adco", "Indore", or other similar process for the effective decomposition of farm organic wastes. Such compost is reserved for use in seed boxes and on vegetable and nursery crops generally. The bulk of the organic manure applied to the field crops is made by a technique first practised in Mauritius, and represents a real advance on the ordinary West Indian method of making pen manure. By the Mauritian process, the first stage in manufacture is exactly the same as for pen manure. All farm wastes along with the requisite amount of green fodder are spread on the floor of the cattle pen daily, and the cattle are penned there overnight. Of the fresh material on the surface they eat what they require and the balance is trampled down and thoroughly mixed in with the nightly droppings of dung and urine from the animals. Care is taken to see that the overflow from the water trough in the pen is sufficient to keep the whole of the litter and herbage thoroughly wet, but not waterlogged. Every 8 to 12 days the pen is cleared out, and on any convenient site near by, the raw mixture of wet litter, dung and urine is built up into a large compost heap some 7 to 8 feet high by 5 to 6 feet wide and any length that the quantity in the pen requires. If the material from the pen is rather dry, it is watered as it goes on to the compost heap, and if the raw manure is over saturated, care is taken to shake it up when it is taken out so as to form a loosely-packed, well aerated type of heap. The compost receives no further attention until the manure is required for applying to the land, which may be anything from one to six months later. The longer the heap is left, the more thorough the decomposition of the vegetable matter and the better the quality of the final product. Decomposition is most rapid in the first few weeks, when, if the proportion of dung to litter is satisfactory and the moisture content of the raw mixture is about right, temperatures go up to about 70° Centigrade. As the compost heap is never turned over after being built, the outer layer is not fully rotted, but this surface material is only a small proportion of the whole heap, and it is bulked in with the rest when the manure goes to the field.

The advantage of this system over the ordinary West Indian process of making pen manure lies in the fact that it ensures a much more advanced stage of decomposition and a better grade of farmyard manure at small extra cost. If the raw materials are merely left in the cattle pen until required for application to the land, the mixture of dung and litter gets so compacted that air is entirely excluded and further decomposition is inhibited by a process analogous to that operating in the manufacture of silage. The resultant pen manure when it is ultimately taken out is consequently only a very slow acting type of fertiliser consisting of a mixture of undecomposed litter and raw cattle excreta. By emptying the pen every 8 to 12 days, the litter and dung do not become too compact and so can be quickly and easily forked out: and by thoroughly washing out the pen on each occasion, the breeding of flies can be kept under reasonable control, as the maggots have not time to develop into adult flies before they are killed off in the compost heap. The very small fly population in the College Farm yard is testimony to the success of the system controlling what is a real pest in most stock areas.

Where so many variable factors are concerned, the crop produce, the field distances, the head of stock, the type and location of the pen, the quality

and weight per unit of the ripe produce, it is impossible to quote a hard figure for the cost of the manure. In the following estimate of the cost per ton of ripe farmyard manure manufactured by the Mauritian process, no allowance has been made for the value of crop residues or surplus herbage forming the basis of the litter, but the cost of carting the former from the field to the pen has been included.

	Cost per ton of raw material in the pen
Carting crop wastes from the field to the pen—	
Men	24c.
Draught animals ...	12c.
Emptying pen every 10 days and building compost heap	
Men	30c.
Draught animals ...	10c.
Total	76c.

During decomposition in the compost heap the raw materials lose by fermentation and drying out, some 50 per cent. of their original weight, so that the cost per ton of ripe farmyard manure at the compost floor is approximately $1.50. In addition, the cost of carting and applying the manure to any crop will have to be added to the cultural expenses for that particular crop. For the above estimates, 70 per cent. of the total represents the cost of manual labour used in the process of manufacture, and the remaining 30 per cent. the cost of the draught animals pulling the carts. Today with the existing inflated labour rates, the cost per ton of making manure by the same process will be some 75 per cent. to 100 per cent. higher than the figure quoted.

Peasant Settlements in Relation to the Tabulated Data

Size of Holding

Realising that the method of approach is neither the only nor the best one, but because at present information on the subject is very meagre, it is proposed tentatively to use the data to form an estimate of the number of acres of land a peasant and his family can be expected to cultivate with the assistance of one draught animal. No excuse is offered for making this attempt from admittedly very limited data for it is of the first importance in any scheme of land settlement that the size of each holding should come within a certain restricted range around the optimum size for any given environment and system of management. If the acreage is too small, the holding can never be self-supporting ; while if it is too large proper cultural control of the land upon which the success of the project ultimately depends becomes impossible. First of all, we would postulate that our peasant grows crops of the same general class as those analysed, either in rotation or, whenever feasible, in mixture. It will be assumed that the family consists of a man and his wife and one boy of working age and that the man and youth work 240 days each per year, and the woman 120 days, making a total of 600 labour days for the family. By West Indian standards, the assumption that the men will work two out of every three days in the calendar year is probably a high estimate of the number of full working days spent in the field. This may be counterbalanced by the fact that the tabulated data forming the basis of our calculations are for paid labourers working an eight-hour day, whereas the rate of output by a farmer on his own land is likely to be higher than that of the wage earner. Furthermore, although the total number of days the smallholder spends in the field each year may not amount to quite 240, he will offset this by putting in occasionally as his crops demand, a 12–14 hour day at the most effective times. The woman's working year has been put at half that of the man's or only one-third of the calendar year, as in all probability her family duties and household tasks will leave her with less opportunity for field work.

It is necessary now to postulate the cropping, and in the following calculations it will be assumed that half the annual crop acreage is devoted to long season annual or biennial crops with a high labour requirement like yams, pigeon peas or sugar cane and the other half to short season annuals with a relatively much lighter labour demand such as maize, pulses, rice or sweet potatoes. Of the first category the peasant family could cultivate some 2 acres, which might comprise $\frac{1}{2}$ acre under yams, $\frac{3}{4}$ acre under pigeon peas, and $\frac{3}{4}$ acre of sugar cane. By College Farm standards, the cropping, cultivation and harvesting of these crops or their equivalents in other species would require on the average some 350 labour days. For the short season crops there might be $\frac{2}{3}$ acre under maize or other cereal, $\frac{1}{3}$ acre each under pulses, sweet potatoes and forage grass, which would account for another 130 labour days in all. The fodder grass has been included in this latter category because, although it is likely to be a perennial, its labour requirement per year is similar to that of the short season crops. This leaves a balance of 120 labour days unaccounted for out of the total available of 600 days per year. It is estimated that this balance of 20 per cent. of the total working year will be required for the hundred and one odd jobs that crop up and have to be done on every farm to keep it operating efficiently. These jobs include road mending, draining, repairs to implements and harness, carting produce to market, composting, for which no allowance has been included in the tabulated figures showing the labour day requirement for each crop.

On these premises it would appear that a peasant family planting the specified assortment of arable crops or their equivalent should be able to cultivate some 4 *crop* acres each year. The climate in Trinidad is such that two or even three short season crops may be grown in succession in the same field in one calendar year, so that on an intensive system of farming, a holding of 3 acres of cultivable land would appear to be the right acreage for a family of three working members.

The Utility of a Draught Animal

For the implemental operations in the cultivation of the four crop acres, it is unlikely that more than 100 animal days could be effectively used, so that one ox or buffalo would be all that the peasant would require or could afford to maintain for draught purposes. The standard of cultivation would therefore be somewhat restricted by this limited power unit of a single ox yoke, and deep ploughing or even ploughing at the height of the dry season would not be practicable. Nevertheless, the 4 acres of crop could not be grown by the family without the aid of a draught animal. Ploughing to a depth of 5 inches to 7 inches and cutting an 8-inch furrow slice, a peasant should be able to plough and harrow in a day $\frac{1}{2}$ acre of land. In contrast, by hand forking, only about $\frac{1}{8}$th of this area could be completed in the same time. It is in this preliminary preparation of the land for sowing that the possession of a draught animal would be of the greatest utility to the peasant, especially as the larger area covered in a day means that cultural operations can be completed more nearly at the optimum time when soil and climatic conditions are just right. But even for inter-cultivation and harvesting operations, animal draught should mean a considerable saving in the amount of manual work required by each crop and so lead to a significant increase in the total acreage that a smallholder could effectively cultivate. For handling crop residues, applying farmyard manure, taking produce to and from market, it is certain that the use of an ox cart means a real economy in the operation of any holding. In fact it may safely be assumed that where no draught animal is available, the cultivable acreage that the peasant family could look after will not be more than one-half what it could work with implemental aids, or on the intensive system of cropping already cited, a maximum of only $1\frac{1}{2}$ acres of land.

The maintenance costs of keeping one draught ox need not be high ; for provided a good type of roughage is used, concentrate foodstuffs are not essential to keep the animal in satisfactory condition. In the insular tropics, the roughage requirement of cattle can be simply and economically provided for by planting and cultivating a small area of a suitable perennial fodder grass such as elephant, Guatemala, or Para grass. If cut over in rotation at 6 to 10 week intervals, any of these grasses with proper attention and management should yield at a conservative estimate from 25 to 30 tons of nutritious herbage per acre per annum, and under good environmental and cultural conditions may give up to 50 tons green fodder per year. Depending on the species, the season of the year and the age of the herbage when cut, a 1,000 lb. ox will require from 60 to 100 lb. of green fodder per day or about 13 tons per annum. The cultivated forage will be supplemented from time to time by edible crop residues such as cane tops, legume vines, sweet potato haulms so that $\frac{1}{3}$ to $\frac{1}{2}$ acre of land put down to a perennial fodder grass should ensure an adequate supply of roughage for one ox, and even yield sufficient surplus to tide over an average dry season in Trinidad. The obvious and most effective way of providing for the stock in the dry weather would be to preserve the surplus forage in the wet season in the form of silage, but for some time to come, it is unlikely that the peasant farmer would readily undertake the extra work and care that ensilage involves. An alternative method would be to see that, by careful utilisation of crop residues or other forms of available roughage, at the beginning of the dry season only a small proportion of the fodder area had been recently cut over, so that when the dry weather sets in there will be a good stand of herbage varying in maturity from 4 to 12 weeks old. This would take longer to work round than in the wet season, especially as the dry matter content is higher and a smaller weight of green herbage per head per day would be required. This procedure would really amount to extending the cutting rotation from two to three months, which, along with the limited amount of new herbage developed even during the height of the dry weather, should suffice to tide over the difficult period of the year. The technique has the disadvantage that even the slightly increased number of weeks between harvests means the feeding of older, less nutritious and more fibrous herbage, and it also leaves a very small margin of safety in the supply of roughage to cope with emergencies such as an excessive or prolonged drought.

There can be little doubt that where conditions permit of its use and the full cultivable area is available, the possession of a draught animal is of real advantage to the smallholder. It should mean doubling the acreage of crops that can be grown annually, an improved standard of cultivation, a greatly increased total quantity of produce for sale or home consumption, and perhaps most important of all, a ready means of producing good grade farmyard manure at small cost. By one method or another, the maintenance costs in the insular tropics can be kept very low, and in suitable localities it can be confidently stated that the use of livestock in the cultivation of peasant holdings does greatly enhance their chances of success.

The Minimum Holding

While it is important to know the total area a family could cultivate under a specified system of management and field conditions, it may also be instructive to calculate the minimum area that will provide a living to a peasant who exercises reasonable industry and skill in the cultivation of his holding. Apart from specifying that the land has to be cropped intensively, it is obviously not feasible here to define more exactly the system of management, although it is recognised that the success of any holding will be largely dependent on whether the rotation of crops practised is or is not really suited to the environmental conditions as a whole. It is the crop rotation which determines the sequence of cropping, the annual acreage

of each crop, the quantity and proportions of each type of produce, the distribution of labour throughout the year and even the maintenance of soil fertility, and there is a real need to work out and test in practice a sound rotation for each settlement area. Further discussion here would be redundant, but it will be assumed that a good variety of different types of crop is to be grown so as to ensure a sufficient range of foodstuffs to give some degree of balance in the dietary. Seagar* records data to show that in 1930 the East Indian labourer on a sugar estate in Trinidad consumed per diem an average of 2.56 lb. of a mixed ration of vegetable and animal foodstuffs of which the main staples were rice and flour, followed by roots and pulses. The components of animal origin in the ration consisted of fish, meat, milk and eggs, which were present, however, in too small quantities to give a reasonable protein balance. Seagar also estimates that the total caloric value of the ration amounted to 3,183 Calories per day, whereas for the adequate nutrition of a field labourer some 4,000 Calories are required. On this latter basis, a peasant growing the variety of crops already suggested would have to consume daily a bulk ration equivalent to $2\frac{1}{2}$ lb. roots, 1 lb. cereals, $\frac{1}{2}$ lb. pulses, which would provide him with the full theoretical requirement in Calories, as evaluated in Table 1.

Using Armsby's thermal equivalents*, the aggregate caloric value of the above totals for the proximate constituents of the ration amounts to 4,023 Calories, a gross energy value which fulfils the theoretical requirements of an adult labourer.

Taking first of all a holding comprising the full workable area of 3 acres of arable land, and allowing for one-third of an acre out of this area to be laid down to a permanent cultivated fodder grass, for the diversification of crops already specified, in an average year the yields of food crops and the corresponding bulk food consumption of the family, would be as shown in Table 2.

	Therms per 100 lbs
*Vegetable Protein	255.7
Vegetable Fats	429.6
Carbohydrates	189.8

From "The Nutrition of Farm Animals" by H. P. Armsby.

* *Tropical Agriculture*, VII, pp. 40-45 "Labour Efficiency" by E. A. Seagar.

Table 1

Bulk Food Requirement per Adult per Day

Foodstuff.	Quantity. (lb.)	Proximate Composition.					Nutritive Constituents in Ration (Lb.)		
		Dry Matter.	Crude Protein.	Fat.	Carbohydrates.	Ash.	Protein.	Fat.	Carbohydrates.
Roots	2.5	30	1.1	.3	27.5	1.1	.028	.008	.687
Cereals	1.0	87	8.4	2.0	75.0	1.6	.084	.020	.750
Pulses	0.5	87	24.0	1.3	58.3	3.4	.120	.007	.291
Total... ...	4.0	—	—	—	—	—	.232	.035	1.728

Table 2

Crop.	Acreage.	Average Yield per Acre from Tabulated Data.	Estimated Yield of Produce.	Annual Food Requirements of Family.*
		(lb.)	(lb.)	(lb.)
Yams	$\frac{1}{2}$	16,000	8,000 } 9,600 lb. roots	3,200
Sweet Potatoes... ...	$\frac{1}{2}$	4,800	1,600 }	
Maize or other Cereal ...	$\frac{2}{3}$	1,950†	1,300 1,300 lb. cereals	1,280
Pigeon Peas	$\frac{3}{4}$	800†	600 } 750 lb. pulses	640
Cowpea, Woolly Pyrol or Other Pulse	$\frac{1}{3}$	450	150 }	
Sugar Cane	$\frac{3}{4}$	40 tons	30 tons	—
Fodder Grass	$\frac{1}{3}$	30 tons	10 tons	—

* Estimated on a bulk daily ration of 4 lb. each for the man and youth, and 3.0 lb. each for the woman and say one child or a total consumption for the family of 14 lb. foodstuffs per day. On this basis the ration is distinctly generous in comparison with what Dr. Seagar records as the actual diet of the agricultural labourer in Trinidad.

† Seed Yield.

It should be clearly understood that the daily ration of 2½ lb. roots, 1 lb. cereals, and ½ lb. pulses is not suggested as in any way adequate to satisfy the full nutritional requirements of a labourer. Obviously provision will have to be made to replace a proportion of the vegetable constituents of the ration by animal produce—meat, milk, eggs, fats, &c.—in order to improve the protein balance; and green vegetables and fresh fruit will be required to ensure an adequate mineral and vitamin content. Provided the total yield potential of the land is adequate, the necessary balance and variety in the diet may be arranged in several ways; a greater variety of crops, including fresh vegetables and fruits may be grown, some of the crop produce may be transformed into animal produce by feeding it to livestock raised on the holding; or the surplus may be sold and the revenue used to purchase the additional food essentials in the local markets. It is evident from the tabulated data that provided a suitable system of management is followed, the yield potential of the 3 acres of land intensively cropped but with over ⅓rd under fodder or money crops is more than adequate to provide the necessary bulk produce for the maintenance of the peasant household. A good proportion of the total area has been purposely laid aside for the growing of a suitable money crop, and the sale of the produce from this along with any surplus from the food crops not consumed by the family should suffice to raise the standard of living of the peasant household above a mere subsistence level. Actually, the total monetary return that our peasant might expect in an average year would be approximately as follows:—

Money Crop		
Sugar cane: 30 tons per acre at $2.80 per ton	= $84.00	
Surplus from Food Crops		
5,333 lb. Yams at 1½c.	= $80.00	
1,067 lb. Sweet Potatoes at 1½c.	= 16.00	
20 lb. Cereals at 2c.	= .40	
110 lb. Pulses at 4c.	= 4.40	$100.80
Total Gross Revenue		$184.80

Of this revenue, more than half comes from the sale of the surplus food crops valued at retail market prices, and the balance represents cash receipts from the money crop. After deducting from this gross revenue, all the overhead expenses of operating the holding, it is not unreasonable to assume that while the resultant net income should suffice to cover essential living costs of the household there will be little margin left for anything in the nature of luxury purchases.

It is further suggested that on any soil type which in the broadest sense of the term is not more fertile than that at the College Farm, the minimum area from which a peasant family of four could wring a bare living by intensive cropping is about 1½ acres. At this, after the food requirements of the household had been satisfied, the cash revenue from the sale of surplus food or money crops is likely to be meagre, except in unusually favourable seasons. The margin of safety is low, and is aggravated by the difficulty of storing agricultural produce successfully in the tropics, especially when only the simplest, almost primitive, facilities are economically feasible. In fact, the effective storage under peasant conditions, for two or three months at a time, of suitable classes of home grown produce is considered by many authorities to be fundamental to successful land settlement in the West Indies. Of the above crops, yams will store satisfactorily for several months with reasonable care, but the other produce, and particularly the pulses, will require special precautions, and even then a considerable wastage in store is almost inevitable. Very small holdings have the further disadvantage that only intensive cropping will provide the necessary total yield for subsistence, and it is impracticable to rest any reasonable section of the land periodically with a view to soil recuperation by natural agencies. Thus, the smaller the acreage below the optimum size for any given system of cropping, the more difficult becomes the problem of maintaining soil fertility; and the reduction of self contained holdings to the smallest area reckoned to be capable of yielding a living for a peasant family greatly adds to the hazards of the enterprise. On the other hand, on a limited holding, only a portion of the total available working days in the year need be spent in cultivating the holding itself, and the peasant is free on the other days to seek occasional employment for a daily wage on any neighbouring estate. Where such casual work is available, it would represent an effective insurance against bad seasons, even when in a normal year the area of the holding is just large enough to make it self supporting.

General Economy of Peasant Holdings

Thus, for conditions obtaining at the College Farm, a self contained peasant holding managed by a family of three workers with the aid of one draught ox should have an annual *crop* area between 3 and 4 acres, equivalent on an intensive system of management to 2½ to 3 acres of arable land. On a system of mixed farming where the land is cropped less intensively and the maintenance of livestock in addition to the draught animals forms an integral part of the farm economy, some 4 to 5 acres per holding are suggested. Where conditions are such that only hand cultivation can be practised, the size of the holding would have to be reduced to between 1 and 1½ acres, and a potentially more fertile soil type than that at the College Farm becomes really essential if, by means of manual implements alone, the total yield of produce is to be kept at an adequate level to provide a reasonable livelihood for the household. There is no doubt that whether the holding be relatively large or small, a satisfactory standard of living cannot be achieved without fairly regular and steady work in the field by all the adult members of the household, and it remains to be seen whether such a project would be attrac-

Table 3

	Acreage.	Yield.	Market Price per lb.	Revenue.
		(lb.)	c.	$
Yams	½	8,000	4	320
Sweet Potatoes...	¼	1,600	4	64
Maize	¾	1,300	3	39
Pigeon Peas (Seed)	¾	600	10	60
Cowpeas	⅛	150	8	12
Sugar Cane	1	30 Tons	$3.70 per Ton	111
				$606

tive to the average labouring family. For example, assuming a ready market for all classes of agricultural produce, the gross annual revenue of a peasant who grew the variety and acreage of crops already postulated, fed his family entirely on purchased foodstuffs and sold all his own produce at current rates in Trinidad would be roughly as shown in Table 3.

From this he would have to deduct all expenses for rent, equipment, fertilisers, seed, animal foods, freight and marketing costs, all of which in the aggregate would account for anything between 20 and 50 per cent. of the gross revenue. Nor would it be possible with the existing market conditions to sell all classes and quantities of produce at full market rates, so that the figure quoted for gross revenue is undoubtedly optimistic.

In contrast, if the peasant hired himself and his family out as labourers for the same number of working days in the year, his net revenue would be of the following order:—

Man for 240 days at $1 per day	...$240
Youth for 240 days at 80c. per day	... 192
Woman for 120 days at 50c. per day	... 60
Total	...$492

Even making allowance for the fact that the smallholder working his own land in his own time does not usually expect the same monetary return per working day as the wage earner, there is little doubt that on the above balance sheet the financial situation of the hired labourer is better than that of the peasant farmer. The former, not only receives a bigger net income than the smallholder could normally achieve but also has none of the risks attaching to any farming project subject to the vagaries of climate, soil and market prices. Admittedly the present conditions in Trinidad are abnormal. There is an unusually heavy demand for labour, but it appears certain that sooner or later there will again be an unemployment problem to be faced. This problem already exists in some of the other West Indian islands and the only solution seems to lie in the "back-to-the-land" movement when in areas agriculturally suitable, any *bona fide* farmer should at least be able to make a "living" out of the cultivation of the soil. Actually, the strength of the land settlement policy lies in the fact that it provides a possible solution to an otherwise insoluble economic problem, because the peasant family is in itself the market for the bulk of the produce yielded by the holding, and the peasant is consequently not so subject to fluctuations in the world markets or to changes in the general economic situation. The standard of livelihood may be good, indifferent, or trending from bad to worse, depending on the skill and industry of the farmer, on the soil and field conditions, on the system of management and the variety and rotation of crops, and particularly on the seasonal factor. With problems of soil erosion, fertility maintenance, pests and diseases, bad seasons, praedial larceny, serious competition all to be contended with, there is no easy living to be had even under the most favourable conditions of soil and situation. In the writer's opinion, the number of difficulties that will have to be faced and overcome, is such that any attempt to establish permanent settlements in areas known to be seriously handicapped from the start by such factors as poor, exhausted or intractable soils, unsuitable topography or too steep slopes, uncontrollable wind or water erosion is foredoomed to failure. It is just here that land shortage complicates the problem. This does not alter the fact that in opening up any new settlements, it is of the first importance to select the best possible sites out of the total available areas, and in this selection to use scientific aids in assessing the agricultural value of any locality. Even on a relatively good site, continued successful cultivation will only follow a well planned system of management designed to ensure the maintenance of soil fertility, a proper variety and rotation of crops, and a reasonable distribution of labour over the year; and the greater the environmental handicaps, the greater the skill and care required in planning and practising an appropriate system of management, always remembering that only areas reasonably adaptable to arable or mixed farming in one form or another offer any likelihood of success.

Acknowledgments

Grateful acknowledgment is made to Professor R. Cecil Wood, Professor Emeritus of Agriculture, who up to 1938 when he retired from office was responsible for planning, inaugurating and directing the detailed and comprehensive system of records kept at the College farm. Whatever value the data in this report may have is directly attributable to his efforts in having all farm operations and expenditures carefully

recorded, correctly allocated, and systematically analysed. The writer also wishes to acknowledge his indebtedness to the Principal, Mr. O. T. Faulkner, Professor E. Harrison and other colleagues on the staff for their close study of the original manuscript and for many helpful and constructive suggestions for its improvement.

APPENDIX I

List of Field Crops grown at the College Farm, 1930-40

Adlay (*Coix lachryma jobi*).
Bambarra groundnut (*Voandzeia subterranea*).
Bengal Bean (*Stizolobium aterrimum*).
Broom Corn (*Sorghum vulgare*).
Calopogonium (*Calopogonium mucunoides*).
Cassava (*Manihot utilissima*).
Castor Oil (*Ricinus communis*).
Cauliflower (*Brassica oleracea botrytis*).
Centrosema (*Centrosema pubescens*).
Coriander (*Coriandrum sativum*).
Upland Cotton (*Gossypium hirsutum*).
Sea-Island Cotton (*Gossypium barbadense*).
Cowpea (*Vigna sinensis*).
Dolichos (*Dolichos hosei*).
Elephant Grass (*Pennisetum purpureum*).
Green Gram (*Phaseolus aureus*).
Groundnut (*Arachis hypogea*).
Guatemala Grass (*Tripsacum laxum*).
Guinea Corn (*Sorghum vulgare*).
Hill Rice (*Oryza sativa*).
Trailing Indigo (*Indigofera endecaphylla*).
Kidney Bean (*Phaseolus vulgaris*).
Maize (*Zea mays*).
Niger Seed (*Guizotia abyssinica*).
Onion (*Allium cepa*).
Para Grass (*Brachiaria mutica*).
Pigeon Pea (*Cajanus indicus*).
Pueraria (*Pueraria javonica*).
Roselle Hemp (*Hibiscus sabdariffa*).
Sesame (*Sesamum indicum*).
Sesbania (*Sesbania speciosa*).
Soya Bean (*Soya maxima*).
Sugar Cane (*Saccharum officinale*).
Sunflower (*Helianthus annuus*).
Sunnhemp (*Crotalaria juncea*).
Swamp Rice (*Oryza sativa*).
Sweet Potato (*Ipomea batatas*).
Sword Bean (*Canavalia ensiformis*).
Tephrosia (*Tephrosia candida*).
Tobacco (*Nicotiana tabacum*).
Tomato (*Lycopersicum esculentum*).
Woolly Pyrol (*Phaseolus mungo*).
Yam (*Dioscorea alata*).

APPENDIX II

Data for the Maintenance and Utilisation of an Established Field of Guatemala Grass

	Cost per Acre per Annum.	Per cent. of Total.
Manures and Manuring	$ 8.60	18.3
Supplies	1.63	3.5
Inter cultivation and Weeding	8.20	17.5
Cutting and Carting Herbage to the Cattle Pen	28.50	60.7
Total	$46.93	100.0

	Man Days.	Woman or Youth Days.	Mule Days.	Ox Days.
Labour Requirements per Acre per Annum ...	33	48	7	20

From the above data, it is evident that some 60 per cent. of the total outlay on a standing field of fodder grass represents the daily cutting and feeding of the green herbage on the soiling system. The actual cultural expenses required to maintain a good healthy stand of the forage grass are low. By planting a species of fodder crop such as elephant or Para grass which may be grazed without affecting the ratooning capacity of the stools, a considerable saving in the maintenance cost of feeding the stock could be achieved. This would entail a controlled system of rotational grazing by folding or tethering the animals in the field for a good portion of each day, and with draught animals this would only be feasible when they were on light work. By grazing, also, the quantity of farmyard manure that would be available for applying to food crops would be reduced, but on the other hand the grazing animals would provide directly much of the manurial requirement of the fodder grass.

MISCELLANEOUS NOTES

A Manurial Experiment on Coconuts

The results of a manurial experiment on coconuts which were published in the *Malayan Agric. J.*, XXIX, 145–51, revealed that with poor mature coconut palms growing on coastal clay in Malaya a single dressing of ½ ton of lime per acre produced beneficial effects in yield of nuts and weight of copra, lasting over 5 years. The effect of lime was apparently not due to calcium ion but, it is suggested, to over coming aluminium toxicity. Investigations of this latter hypothesis are to be continued. The slight response to phosphate indicated seemed to lie in more nuts than in increased copra content.

A New Strain of *Crotalaria juncea*

The Proefstation voor Vorstenlandsche Tabak, Java, as a result of selection over a period of 10 years has produced a strain of *Crotalaria juncea* which, as a green manure, yields about 18 per cent. more material than unselected strains. Because of coss-pollination it is difficult to keep the strain pure and planters in possession of the improved strain are recommended to save and select their seed from an isolated batch which they should grow specially for the purpose.—(*Horticultural Abstracts*, XI, No. 3, 1941.)

A DISCUSSION OF RESEARCHES ON THE SUGAR-CANE FROGHOPPER (HOMOP., CERCOPIDAE)

BY

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1. Introduction

The sugar-cane froghopper, *Tomaspis saccharina* Dist., has been recognised as a serious pest of sugar cane in Trinidad since the year 1889. Injury to the cane is caused by the feeding activities of the adult insects, which puncture the cane leaves with their stylets and whose feeding activities give rise to a complex of symptoms resulting, in cases of severe attack, in the death of the greater part of the functional leaf tissue. Destruction of the leaves in this way is followed by the death of young shoots and frequently by atrophy of the roots and may culminate, at best in a serious reduction of the yield of cane per acre, at the worst in the death of the plant.

After many years during which the attacks of the insect have been of limited severity and distribution, three successive years, from 1939 to 1941, have been remarkable for extremely serious outbreaks of the pest. It is true that the greater part of the sugar growing area of Trinidad has been free from infestation, but the damage caused in affected districts represents a serious financial loss to the sugar industry. Omitting cane lands operated by small farmers, for which no data are available, 12,000 acres were severely damaged in 1939; in 1940, 10,000 acres of estate canes were severely blighted and in 1941 the damage was particularly intense, although only some 6,000 acres were seriously affected.

In spite of the indications to the contrary given by earlier experience and research, it now seems certain that reasonable assurance against destructive froghopper outbreaks cannot be given by the employment only of cultural methods of control. The efforts made to establish a means of biological control have met with no success and no natural enemy worthy of introduction has been encountered since 1911. Of the insecticidal methods of control which have been advocated, the employment of Cyanogas and pyrethrum dusts has not been generally adopted, although good results are claimed for these methods by those estates which continue to employ them. It therefore seems desirable that serious consideration should be given to the future policy in regard to froghopper outbreaks, to the means at our disposal for minimising their effects and to plans for future investigation.

2. Historical Summary

1889.—J. H. Hart pointed out that "blight", which had been known for several years to affect sugar cane, was caused by the feeding activities of the froghopper. He detected green muscardine fungus destroying froghoppers (12, p. 127).

1907.—O. W. Barrett, while agreeing that froghoppers were numerous on blighted canes, believed the condition to be due to a fungus disease and recommended spraying with Bordeaux Mixture. This was subsequently found to have no effect (1, p. 99).

1909.—Following the severe outbreaks of 1906, 1907 and 1908, the newly formed Board of Agriculture appointed staff for special study of froghopper blight.

1910.—L. H. Gough was especially engaged by commercial interests to conduct froghopper studies. As a result of one season's experience, he recommended (6): (*a*) sprays of nicotine and of oil emulsions to destroy the insects; (*b*) propagation and artificial spreading of green muscardine fungus; (*c*) use of light traps. He discovered the syrphid fly whose larva is predacious on froghopper nymphs.

1911.—F. W. Urich introduced the "Mexican Bug" from Vera Cruz, but the insect failed to survive (38).

1912.—P. L. Guppy discovered the "Vermilion Parasite" of froghopper eggs (2).

1913.—Guppy discovered the "trash coloured parasite" of froghopper eggs. J. C. Kershaw was engaged for special froghopper studies, following the particularly severe outbreaks of 1911 and 1912. He recommended (13) mass propagation and liberation of the syrphid fly and, if satisfactory control were not obtained in this way, a search for parasites on the American mainland.

1914.—Guppy attempted to breed the syrphid fly in captivity and succeeded in carrying a few individuals through the dry season (7).

1915.—Guppy's attempts to colonize the syrphid fly were abandoned as impracticable.

1916.—C. B. Williams was appointed to conduct a search for foreign parasites as recommended by Kershaw.

1917.—Williams discontinued the search for foreign parasites and commenced a detailed study of froghopper problems in Trinidad.

1918.—Uba and Badilla were found to be the only varieties appreciably resistant to froghopper.

1920.—Nowell and Williams considered that the development of an active form of root disease was the most important effect of froghopper attack and that the development of root disease could be prevented by appropriate cultural treatment (20, 21, 22, 43, 44).

1921.—Williams published a final report (43) on froghopper studies and recommended (*a*) improvement of drainage; (*b*) increased use of lime and pen manure; (*c*) improvement of tillage; (*d*) reduction of ratooning; (*e*) rotation of crops; (*f*) weeding and trashing to destroy eggs; (*g*) capture of adults by nets and light traps; (*h*) search for natural enemies outside the American area, especially in Africa.

1925.—Following a severe froghopper outbreak in 1924, representations were made to Government resulting in the formation of the Froghopper Investigation Committee.

1926-7.—The principal studies were devoted to biochemical work and the investigation of soil characters in relation to the froghopper problem under F. Hardy and P. E. Turner.

1928.—A programme for biological control work (14) was submitted by J. G. Myers and the Committee promised its co-operation.

1929.—The intensity of froghopper damage in blighted areas shown to be related to the degree of lime deficiency of the soil (34). A. Pickles appointed as Entomologist in connection with the biological control programme. A Cuban parasite of froghoppers was found not to attack the genus *Tomaspis* (15, p. 344).

1930.—A search for froghopper parasites was conducted in Jamaica, but without practical results (23). Two new egg parasites were discovered in Trinidad (24). Froghoppers were found to lay chiefly in soil and only to a limited extent in cane trash (26).

1931.—Centres of froghopper outbreak were successfully forecast by a survey of egg distribution in the dry season (27). Moderate dressings of lime to the soil shown to improve the yield of blighted canes more than of unblighted canes (35). A survey of blight distribution following the severe outbreak of this year afforded no evidence that lime applications could prevent blight incidence (Pickles, A., unpublished report). The average loss due to froghopper attack found to be between seven and nine tons of cane per acre affected.

1932.—Myers and D. V. FitzGerald commenced a search for froghopper parasites in British Guiana and Brazil. Detailed information was obtained on the activities of froghopper parasites in Trinidad and on the effect of tillage on froghopper incidence (25, 26). The variety Co 213 was recognised as definitely resistant to froghopper blight. Eggs of the sugar-cane froghopper were shown to vary in susceptibility to desiccation (28, p. 111).

1933.—The production of froghopper resistant canes was adopted as an official object by the Central Cane Breeding Station. Myers and FitzGerald returned from Brazil, but no new parasites had been discovered (19). Myers and Pickles left for a second journey to Brazil. Stool shaving was found to reduce froghopper populations slightly but caused serious depression of cane yields (39, 40, 41).

1934.—The search for froghopper parasites in Brazil concluded without practical results (17, 29). Co 213 was shown to be less attractive to feeding froghoppers than other familiar varieties (30, p. 381).

1935.—Recovery from froghopper damage shown to be slower on unlimed and over-limed than on suitably limed acid soils (36). Attention was again paid to the relation between froghopper attack and root injury.

1936.—Pyrethrum was suggested as a possible insecticide for froghopper control (32). Studies on varietal resistance were continued by the Imperial College of Tropical Agriculture.

1937-38.—Experiments with pyrethrum continued.

1939.—Preliminary evidence was adduced suggesting a relationship between soil type and intensity of froghopper injury (37). Pyrethrum found to be highly toxic and to produce a high mortality when applied on a field scale (33). An olfactory attraction of froghoppers to certain cane varieties suggested as a cause of susceptibility to attack (4).

1940.—Pyrethrum dusting was tested on several estates, with success at Woodford Lodge Estate but not elsewhere.

3. Cultivation and Manuring

The great variations in the severity of damage to sugar cane which may follow froghopper attack have always attracted attention and, from an early stage of the investigations, have prompted the view, once widely current, that "healthy" canes resisted froghopper attack, while "unhealthy" canes were susceptible.

Nowell and Williams suggested that an active form of root disease generally followed froghopper attack and was its most serious consequence. The effect of an outbreak of froghoppers could therefore be minimised by employing those cultural measures which were known to control ordinary outbreaks of root disease, particularly improvement of drainage, deep cultivation and increased use of lime and pen manure.

Critical field experiments, conducted under the auspices of the Froghopper Investigation Committee, showed that the yield of cane from limed experimental plots was definitely greater than that from unlimed plots in the same area when both had been attacked by froghoppers and similar differences were observed subsequently when comparing the effects of varying nutrient applications. There is no indication, however, that any liming, manurial or tillage treatment can *prevent* blight development when the area in question is exposed to a severe or even moderately severe froghopper attack and no such treatment appears to give any assurance that a severe froghopper attack will not develop. Still less is there any suggestion that froghoppers will avoid canes growing in plots so treated in favour of the untreated plots.

The explanation of the observed facts appears to be that many environmental factors can arrest the development of cane roots and can even cause an active deterioration of functional roots, although a definite fungus disease of the roots is probably not necessarily an immediate cause of this condition. Root atrophy of this nature may occur through prolonged water-logging of the soil, excessive and unchecked weed growth, marked nutrient starvation, lime deficiency in certain circumstances and finally, from a severe froghopper attack. If several of these factors operate simultaneously, root atrophy is produced by comparatively small displacement of each individual factor from the optimum. Thus, if drainage, lime status and nutrient status are all good, a very severe froghopper attack will be required to produce root atrophy; but if drainage

is poor or if soil is deficient in lime or nutrients, a comparatively light froghopper attack will induce atrophy of the roots and the injury to the crop will be as serious as if the froghopper attack had been severe.

Observations extending over many years indicate that the application of lime to the soil of cane fields does not perceptibly affect the magnitude of the froghopper populations. On the other hand, in an area in which lime is acting in a limiting capacity on general growth, the condition of the canes some weeks after a moderate froghopper attack will be good or bad according to the lime status of the soil.

Certain types of soil support canes which are seldom subject to severe blight, and call for passing mention here. According to estates returns, froghopper injury has occurred on such soils more frequently than is generally realised, but the depression of yield of the cane is seldom serious. Such soils are usually high in lime content. The explanation appears to be that these soil types are unsuitable for egg-laying of froghoppers unless they are in a water-logged condition, a state of affairs which seldom arises, and the canes therefore are rarely exposed to mass attack by froghoppers. In addition, the general growth conditions are usually extremely good in such cases, root atrophy after the attack does not develop to a serious extent and recovery also is good. The relation between lime status and freedom from froghopper *attack* has probably been over-emphasised in the past; in the case just discussed high lime content and unsuitability for froghopper oviposition may well be coincidental characters of the soil rather than cause and effect.

The importance of tillage methods, drainage, lime and nutrient status of soil in efficient cane production are now fully realised and, in many cases, details of the requirements of various soil types are known. It therefore seems probable that the effects of mild froghopper attacks, such as occur under average weather conditions, are of less economic importance now than they were ten or fifteen years ago and will continue to decrease in importance. The real problem has become one of dealing with outbreaks of unusual severity which occur two or three times in each decade. Such severe outbreaks are dependent principally on weather conditions and the main climatic factors resulting in severe outbreaks are known; the reasons for local variation in the severity in a given year are still obscure.

4. Insecticidal Methods

"Cyanogas"

Following experiments by F. Hardy, Follett-Smith and others (3, 5, 8, 9, 10, 11), "Cyanogas" calcium cyanide was recommended as an insecticide for the destruction of froghopper nymphs in the field. The powder is applied from hand dusters directly on to the spittle masses of the insects which are concentrated at the surface of the soil around the base of the cane. This insecticide was used in large-scale experiments on nearly every sugar estate in the Colony and its routine use was adopted on most, at least for a time. In 1931 however, extremely severe blight occurred in a large proportion of the sugar fields in spite of the use of "Cyanogas" on an unprecedented scale; since that time the use of "Cyanogas" has been less general.

Whether "Cyanogas" is or is not a practicable method of control may therefore be a controversial subject, but the writer's views, based on observations in many localities and extending over several years, may be worthy of record.

For efficiency in the use of "Cyanogas," cane should be clean-weeded and trashed before the powder is applied. The material must come into actual contact with the spittle masses surrounding the insects and its utility will be seriously reduced if a large population of the nymphs is situated beneath the soil. Extremely careful supervision is essential. "Cyanogas" is not effective if used much before or much after the peak of the nymphal emergence and, if the nymphal population is extremely large and its emergence is very protracted, "Cyanogas" dusting is insufficient to prevent serious blight.

The chief difficulty in the effective use of "Cyanogas" is that it makes heavy demands on the labour supply and, in the case of a very widespread outbreak of froghoppers, the whole of the affected area cannot be treated in time to prevent damage.

In consequence, "Cyanogas" can usually give good results when the froghopper outbreak is only moderately severe and when the area affected is restricted, provided the fields are clean and that the work is carried out under proper supervision. In other cases, the results are generally unsatisfactory.

Pyrethrum

Small-scale field experiments suggested that pyrethrum dust might be employed for the destruction of adult froghoppers (32). In 1939, the first attempts were made at practical control of froghopper outbreaks in this way. Pyrethrum in admixture with sulphur was applied at night to infested fields from a large dusting machine, hauled and operated by a high-powered tractor and the insecticide was allowed to drift over the field in the light, steady breeze which usually prevails at this time. It was found that a high mortality of froghoppers could be obtained in this way and, although second brood blight was not prevented in the treated fields, fields receiving pyrethrum dust were much less severely damaged than were untreated fields in which the initial froghopper populations had been considerably smaller and moreover gave a satisfactorily greater yield. The third brood attack, which was somewhat less severe and definitely less widespread than the second, was easily controlled completely by the new method.

In 1940, a still heavier froghopper outbreak occurred on the estate where most of the experimental work had been conducted. In some parts of the estate pyrethrum alone was used for

roghopper control, in other parts "Cyanogas" was employed to destroy the nymphs, followed by pyrethrum for the destruction of adults. In all cases extremely satisfactory results were obtained and the area in which blight occurred was of negligible extent. In all the fields where "Cyanogas" was used adult froghoppers still emerged in numbers which would have been sufficient to damage the canes severely if no further action had been taken, but the subsequent use of pyrethrum in these fields prevented damage developing. Where pyrethrum alone was employed repeated dusting was found to be necessary; on the average, three or four treatments were required and, in specially heavily attacked fields, as many as six or seven. On other estates satisfactory results were not obtained, probably on account of the difficulty of rapidly acquiring the technique, delay in the commencement of operations owing to late delivery of the machinery and, possibly, some variation in the toxicity of the insecticidal material.

Successful use of pyrethrum for froghopper control demands skill and experience on the part of the operators and the method is not one which can be left to ordinary labour. It also requires an intimate knowledge of froghopper populations throughout the estate and constant checking of field results. One serious objection to the method is that work must be performed at night in addition to the routine day's work of the estate staff and the demand on their time and energy is severe when the froghopper outbreak is large. Increasing experience also indicates that pyrethrum is occasionally subject to variation in its toxic power and the results obtained may be variable.

On the other hand, large areas can be treated in a short time with pyrethrum and, when the requisite experience has been gained, high froghopper mortalities may be produced without difficulty. Continued investigation should make it possible to improve the ease and efficiency of the method very considerably, most probably by increasing the toxicity of the dust by addition of other insecticides, such as derris or synthetic products.

5. Biological Control

From a very early stage in the investigations, the possibility of the control of the sugar-cane froghopper by means of natural enemies has received careful attention. A means of control which, having once been set in motion, requires no further expenditure, must naturally be attractive and the successes which have been obtained by biological control of crop pests in other parts of the world definitely justify very careful consideration of the possibilities of this method with reference to the sugar-cane froghopper.

So far as the froghopper problem is concerned, the interest in biological control was originally inspired by the belief that froghoppers occur in many of the sugar-cane growing regions of the American mainland, but cause no serious injury to the crop. It was considered possible that injury in these cases was prevented by the presence of efficient natural enemies which might be suitable for establishment in Trinidad where there was a chance of their performing similar work.

It is therefore of interest to consider how far this original thesis can still be maintained in the light of later information and to what extent the investigations may encourage further efforts in this direction.

History of the Investigations

The first effort to introduce a natural enemy of the sugar-cane froghopper was made in the year 1911, when the late F. W. Urich introduced the "Mexican Bug" from the State of Vera Cruz, Mexico. This predator failed to survive when liberated in Trinidad (38).

In 1913, J. C. Kershaw, who was engaged for one year for special froghopper studies, recommended that efforts should first be made to carry the syrphid fly predator, already occurring in Trinidad, through the dry season in captivity in order that large numbers could be liberated in the cane fields as soon as froghopper breeding commenced. It was hoped that, in this way, the predator would become active early in the season, thereby reducing froghopper populations before serious damage occurred. If this method should prove unsuccessful, an effort was to be made to introduce natural enemies from overseas (13). In spite of most painstaking work of a high standard, the first part of these recommendations was found to be impossible of fulfilment and the work was abandoned in 1915.

In the following year (1916), C. B. Williams was engaged to make a search for foreign parasites in accordance with the second part of Kershaw's recommendations. In the course of his studies Williams visited British and Dutch Guiana, Tobago Venezuela, Canal Zone, Panama, Colombia, Martinique and St. Lucia. These investigations, brought to light one egg parasite in Panama which however was extremely rare and of which froghoppers were probably only an occasional host (44). The work was discontinued in 1917. In 1928 J. G. Myers commenced a study of biological control of West Indian pests on behalf of the Empire Marketing Board and froghopper studies were included in his programme. Myers had already recorded a nymphal parasite affecting another genus of froghoppers in Cuba but, on investigation, this was found to be useless for the control of *Tomaspis* (15). Journeys in search of froghopper parasites were continued with some interruptions until 1935 and with the collaboration from time to time of D. V. FitzGerald and the writer. Investigations were made in most of the islands of the Greater and Lesser Antilles, British and Dutch Guiana, Venezuela, Colombia, Panama, Costa Rica and the Lower Amazon Valley (16, 17, 18, 19, 29, 31).

Discussion of the Results

Twenty-four species of *Tomaspis* and probably half a dozen species of other genera were studied in greater or lesser detail by the investigators. By all, fungus enemies were found to be probably the most important natural control of froghoppers, both in natural habitats and in cultivation. In many cases where the eggs were examined, egg parasites were discovered, but never more abundantly than in Trinidad. Froghopper nymphs were preyed upon in nearly every region by syrphid fly larvae, identical with, or closely related to, the species occurring in Trinidad (31). Other natural enemies were mostly general predators, such as spiders, wasps, lizards, birds etc., and none of these made froghoppers the major part of its diet.

Many of the froghoppers encountered differed essentially from the Trinidad species in life history and habit. Many species laid their eggs in the tissue of the host plant rather than in the soil and it is improbable that an egg parasite of such a froghopper would be of any use in controlling the sugar-cane species.

Little of the American continent however, has really been investigated. The great sugar growing regions of Pernambuco, Baia, Minas Geraes and São Paulo have not been visited; the cultivations in Tucuman, which lie outside the tropics in Argentina, and the Peruvian sugar fields, in irrigated valleys near the Pacific Coast, likewise have never been studied. Probably over a hundred species of *Tomaspis* remain to be studied before every possibility has been completely investigated. It is by no means certain, even, that every froghopper occurring in the regions visited has been discovered.

Nevertheless, it is considered that further exploration of the froghopper problem in South America is unlikely to yield results of any practical value. Previous results have failed to bring to light any froghopper parasite of an essentially new type; in Trinidad, as in Jamaica, Panama or the Amazon Valley, the principal natural enemies appear to be minute egg parasites, syrphid flies of the genus *Salpingogaster* and fungi similar to green muscardine or *Empusa*. It is highly probable that a similar experience would be encountered in the remaining parts of the continent with the possible exception of the coast lands of Peru and Ecuador, west of the Andes. Even the original premise is less accurate than was believed, since froghoppers are now known to be pests of considerable economic importance in sugar-cane districts of South Brazil.

In the writer's opinion, further special investigations abroad on the biological control of the froghopper would be unwise unless a promising parasite is reported by foreign scientists to occur in their territory.

6. Varietal Resistance

The study of varietal resistance begins with the enquiries of C. B. Williams who, as a result of personal observations and the information received in reply to a questionnaire, found Uba and Badilla to be the only varieties then in cultivation which showed appreciable resistance to froghopper injury.

In the severe outbreak of 1931, Co 213 was noticeably less severely damaged, both in experimental plots and on a field scale, than other varieties. More recently, several other varieties have exhibited marked powers of resistance. The production of resistant varieties has been adopted as an object of the Central Cane Breeding Station in Barbados.

It seems probable that the various cane breeding organisations will, from time to time, produce new varieties of which a proportion may be resistant to froghopper damage. For rapid progress on these lines, however, it is essential that the characters producing "resistance" should be elucidated in some detail for the guidance of the cane geneticists, a task which so far has barely been attempted.

"Resistance" seems to depend on many characters which may differ in relative importance according to circumstances. In the first place, a cane variety might owe its apparent resistance to the fact that it is avoided by feeding froghoppers or to the fact that froghoppers are unable to puncture its leaves. When froghopper populations are small, the variety Co 213 seems to be avoided by froghoppers and its reputation as a froghopper resistant variety may be due in part to this circumstance.

A cane which could be exposed to heavy froghopper attack without suffering serious root atrophy and the associated secondary leaf symptoms could be regarded as resistant to a valuable degree. This appears to be the most important character at present distinguishing between resistant and susceptible varieties and it should be possible to multiply the number of varieties exhibiting it. PR 803 exhibits this character in a marked degree and may have its leaves heavily streaked with froghopper marks without undergoing any deterioration of roots and with little marginal leaf wilt, when varieties such as BH 10/12, B 3013 and even B 3439 are almost destroyed in adjacent plots.

Other symptoms of a secondary nature which are associated with blight include reduction in size of fully developed joints, production of adventitious side-shoots from many of the upper joints and prolonged suppression of tiller formation. All these symptoms have a very detrimental effect upon the yield of blighted canes and a variety in which they are not developed could be regarded as commercially resistant to a certain extent. The variety B 3439 appears not to exhibit severe joint reduction and may prove to be useful in froghopper areas on that account.

A cane which, while suffering from all the usual concomitants of froghopper attack, is yet able to recover rapidly, by producing new leaves and roots and new tillers without delay after the attack has passed, would be commercially valuable and the production of such a cane might well be considered in a breeding programme.

It also seems possible that resistance might be exhibited by canes which react but slightly to the enzymes injected into the leaf tissue by froghoppers in the course of feeding. There is some evidence that, in certain varieties, the area of dead tissue which ordinarily develops around the feeding puncture is of smaller size and that the injection of toxic saliva does not always result in the death of leaf tissue.

The investigations necessary, if full use is to be made of varietal resistance, would involve careful recording of the behaviour of existing commercial varieties during and after a froghopper attack, careful note being made of the magnitude of the froghopper populations and of the nature of the soil in each case; similar observations with parental types and arbitrary crosses of no commercial value also seem to be necessary in order to detect the possible inheritance of characters causing resistance. Side by side with the field experiments, a programme of root studies would probably be necessary, together with comparative morphological studies of the various types.

7. Difficulties of Froghopper Investigation

The chief difficulty in froghopper investigation is that the effects of particularly severe froghopper attack differ in kind as well as in degree from those of milder outbreaks. Observations, made over a period of years when mild outbreaks are the rule, consequently afford little guidance for the measures to be adopted when a really serious infestation occurs. This fact has undoubtedly restricted the value of the recommendations of many of the earlier specialists who were engaged for brief periods immediately after a severe outbreak and who were consequently able to study only the features of mild infestations.

When froghopper populations are extremely large, the insects show much less selectivity in behaviour than is usual. In such years, plant canes are frequently severely attacked, while they usually escape injury in average years; the yield is seriously reduced in all the affected fields regardless of cultural treatment if the attack is severe, while yields may be little affected in the best fields in a year of low froghopper incidence; comparatively simple methods of direct control will easily prevent injury in the one case, while unremitting vigilance and energy are required to produce a similar result in the other.

In consequence, the research worker may find, after embarking on a programme of investigation, that his experimental plots are free from froghopper attack for several years in succession and the conclusions which he draws from his general observations and experiments during such years give inadequate information for dealing with a severe outbreak.

The question of specialised research on froghopper problems must therefore be approached with caution if the results are to be comparable with expenditure.

8. Suggestions for Future Investigations

Chemical studies and investigations of biological control in relation to the froghopper problem have already been discussed. With regard to the former, the writer believes that the findings of soil chemistry have already done much to minimise the effects of froghopper attack of moderate severity and the efforts towards general improvement of manurial and tillage treatments, which are likely under existing circumstances to increase, will gradually lead to even more decisive results in this way. Biological control, it is believed, should be studied further only when there is definite evidence suggesting that promising parasites or predators occur in a known locality.

In spite of the progress which has been made and which is likely to continue in chemical and soil studies, it seems certain that extremely severe froghopper outbreaks will continue to occur two or three times in each decade, and if serious losses on these occasions are to be prevented, entomological investigations must be continued assiduously and energetic action must be taken as the outbreaks occur.

It is claimed, however, that entomological investigations can be narrowed in their scope as a result of recent observations and developments; the period of search for avenues of investigation is believed to be over and attention can now be concentrated on methods which give definite promise of success.

In the first place, there is definite assurance that certain cane varieties will give a reasonably good yield under conditions of froghopper attack which would destroy many of the standard varieties in cultivation. It therefore seems reasonable to make a detailed study of this aspect of the problem in close collaboration with the Central Cane Breeding Station and a recent resolution of the Management Committee of the Station endorses this opinion.

In the second place, it is claimed that insecticidal treatment of infested sugar cane can already prevent serious losses arising from froghopper attack, but the work is arduous and somewhat variable in results even with the greatest of care and the fullest appreciation of its requirements. Efforts towards improvement of drift dusting for froghopper control would be justified and, having regard to the several possible improvements in material, which have not yet been examined in relation to the froghopper problem, the writer is confident that the method can be made easier of application and more constant in results.

9. The Present Position

It is unusual for froghopper attacks to remain much above their average degree of severity for several years in succession. That particularly severe outbreaks have occurred during the three years 1939-41 however, gives no assurance that seasons of equal or greater severity will not recur.

Experience shows that unusually high rainfall in the dry season or unusually low rainfall in the wet season are the only factors likely to bring to an end a long series of severe outbreaks.

At the present stage it is important that every estate should decide upon a policy to be adopted if large scale froghopper outbreaks should continue. It is recommended that if this should be the case as many affected fields as possible should be treated with "Cyanogas" during the period of nymphal emergence and, whenever necessary, pyrethrum dust should be applied to destroy the adult insects. "Cyanogas" is recommended as a preliminary to pyrethrum dusting, not through any lack of confidence in the latter method, but to relieve estate staffs as far as possible from excessive night duty.

10. Summary

Measures of improved cultivation and manuring probably have reduced the severity of the effects of relatively mild froghopper outbreaks and may do so to an increasing extent as information is accumulated, but severe outbreaks, which occur several times in each decade, continue to take as heavy a toll as at any time previously unless direct control measures are also employed. Attempts to establish biological control of the pest have met with no success and their resumption is not recommended unless definite evidence is forthcoming of the existence of promising parasites.

Insecticidal control provides the best means at present of controlling froghopper outbreaks and the use of "Cyanogas", followed by pyrethrum, is advocated for this purpose.

Continued investigation of resistant varieties and of insecticidal dusts is recommended, the former to aid in the breeding programme of the Central Cane Breeding Station and the latter to improve the methods available at present.

Should the recent series of froghopper outbreaks continue, it is recommended that every effort should be made to control the infestations by destruction of nymphs with "Cyanogas" dust followed by the use of pyrethrum for the destruction of adult insects.

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MICROBIAL ACTIVITY AS INFLUENCED BY ROOT EXCRETIONS

It is now a well established fact that the growing plant accelerates the activity of soil micro-organisms in the rhizosphere, resulting in a tremendous increase in number. Furthermore it has been shown (*Can. J. Research*, C. 18: 42–53 ; C. 18: 444–456, 1940) that varieties of plants resistant and susceptible to common soil- or seed-borne diseases influence differently the microbial activities in their rhizospheres.

To elucidate the influence of by-products of growing plants upon the activity of mirco-organisms, flax plants of varieties susceptible (Novelty) and resistant (Bison) to Fusarium wilt were grown in modified Crone's nutrient solution under aseptic conditions and 27 days after planting the remains of the nutrient solutions were brought up to the original volume (450 ml.) with distilled water, filtered through the Seitz filter into a sterile container and used for further experiments.

The chemical analyses of these solutions as determined by Bishop's (*Biochem. J.* II, 21: 1162–1167) and Reynolds' (*Ann. Missouri Bot. Gardens* 17: 57–95, 1931) methods, indicate that the solution after growth of Bison contained from 27 to 38 mg. of HCN (per plant) per 450 ml. of solution whereas the solution after Novelty contained only a trace.

The fungi grown on the solid and liquid media prepared with these solutions were influenced differently. Thus growth of Fusarium culmorum and of Helminthosporium sativum was retarded by the solution after growth of Bison, whereas the growth of Trichoderma viride was stimulated, as compared with the growth obtained on the control solution. The solution after growth of Novelty, on the other hand, stimulated the growth of Fusarium and of Helminthosporium. Growth of Trichoderma, however, was not as good as in solution after growth of Bison. The addition of glucose to the media, stimulated the growth of all fungi ; however, the difference between the by-products of growth of the two plant varieties is more clearly indicated.

Thus the results so far obtained indicate that under prevailing experimental conditions resistant flax variety excretes or diffuses through its root system HCN into the surrounding medium. This small quantity of HCN influences the activity of the different groups of micro-organisms differently. —(*Chronica Botanica*, Vol. VI, p. 440.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Treating Sugar-Cane Seeds to Hasten Germination

Satisfactory germination of cane seed has always presented a problem on Hawaiian plantations. This has been especially true with body seed during the cold, rainy months of the year on those plantations which suffer an unusual amount of cloudy, wet weather. A few years ago a new product, Ceresan, was tried by the H.S.P.A. experiment station and was found to aid germination considerably, particularly in the cold, wet lands of the Kailua substation. The Kilauea Sugar Company also laid out some tests with this material and reported very encouraging results. In 1938, all seed planted at that plantation was dipped in Ceresan solution and germination difficulties were reduced to a minimum. During the same year, Lihue plantation planted a field of 32–8560, partly with Ceresan-treated seed and partly with untreated seed. The differences between the two types of seed were so striking that follow-up tests were immediately installed. In nearly every case the results from the treated seed were so favourable that the dipping of all seed in Ceresan solution was continued as a standard practice. Similar results were subsequently obtained by several other plantations on Kuaui. In 1939 most of the plantations on this island treated their planting material with Ceresan. The type of cane variety used in a germination experiment can likewise to a large extent influence the results. Badila benefits only slightly from Ceresan, but varieties with longer internodes, such as 31–2806, respond very markedly. Similarly, the type of planting material used in experiments makes a great difference. The best responses to Ceresan have been obtained with body seed. Where Ceresan has failed to stimulate germination, the reason may often be traced to the fact that top seed was planted. Needless to say, environmental conditions also affect germination. Thus Makaweli with good, deep soils and favourable climatic conditions has not found it necessary or feasible to use Ceresan, but Kekaha, which enjoys equally favourable weather, reports that Ceresan is highly beneficial for germination on their saline flats. In one test on such an area with an extremely high salt content, 90 per cent. of the eyes of seed that had been dipped in one per cent. Ceresan solution and lime germinated. It had been virtually impossible, previously, to secure a satisfactory stand in this field with untreated seed.—(*Sugar*, Vol. 35, p. 32.)

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Soil Acidity for Muskmelons and Sweet Potatoes on Sand Soil

With muskmelons higher yields were obtained at pH 6.0-7.5 than at pH values below 6.0. Sweet potato yields were best from about pH 5.0 to 7.0. Damage due to soil rot was greater at the higher pH values.—(*Chemical Abstracts*, Vol. 34, p. 7511.)

Crops and Micro-organisms

Soil contains quantities of unspecialised bacteria which have hitherto been little studied but are important by reason of their large numbers and variety. There is some suggestion of a relation between cropping and bacterial flora. The process of denitrification whereby nitrates are reduced in the soil to gaseous nitrogen has hitherto been regarded as entirely *anaerobic*. It is now shown that this is not so, and that complete reduction of nitrate to gaseous nitrogen can take place under *aerobic* conditions with the difference that for a C/N ration of 10, the whole of the carbon supplied is used up under aerobic conditions, but part of it is left untouched under anaerobic conditions. Light appears to have no effect on the process.—(*Report Rothamsted Exptl. Sta.*, 1938, p. 46.)

* * *

Potash Requirements for Sugar Cane

It appears that with the formulation of a sound policy of potash fertilization a differentiation must be made between potash uptake by the sugar-cane crop and its potash requirement for optimum yields, because a luxury consumption of potash by the cane plant has been clearly shown. When only the millable cane stalks leave the field, the actual amount of potash that goes with them is not very large. Hence although the total potash taken out of the soil by the growing crop may have been large much of this potash will be left in the trash, tops and roots in the field. There is some indication that the cane plant is able to absorb some potash from a non-exchangeable form that exists in the soil, although the amount taken up is not adequate for optimum yields. Also, it appears that some of the potash applied in the form of soluble salts is fixed in the soil in a non-exchangeable form. As the ratio of tops and trash to the millable stalks is higher in young than in older cane, and as the percentage of potash is also higher in the tops and trash than in the stalks, short crops will need potash at a higher rate per ton of millable cane expected than will long crops. But because the short crops will leave a large amount of their absorbed potash in the tops and trash which are left in the field, a subsequent crop should be able to recover some of the potash.—(*Chemical Abstracts*, Vol. XXXV, No. 18, p. 6376.)

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Preparation of Coconut Shell Charcoal

A method of preparing coconut shell charcoal is described in the *New Guinea Agr. Jr.*, Vol. 7, 204-5; which, it is claimed, has advantages over all other methods previously discussed in that journal. The shells are burnt in 40 gallon oil drums, requiring some easily managed modifications. Much depends on correct stoking. Normal yield is 70-75 lb. of charcoal per drum with volatile matter between 5 and 15 per cent.